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3,758,327

TRANSFER OF LIQUID DEVELOPED ELECTROGRAPHIC IMAGES

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ABSTRACT OF THE DISCLOSURE

A method of transferring a liquid-developed electrostatic charge image from a wet, hydrophobic image-bearing surface of a charge-image-bearing member to a hydrophilic, swellable receiving surface carried on an electrically insulating support which comprised moistening the receiving surface prior to transfer with a hydrophilic liquid of water-containing compositions or alcohol-containing compositions, in an amount effective to increase the electrical conductivity of said receiving surface to a value less than about 106 ohm/sq., electrically biasing the moist receiving surface utilizing an applied potential greater than about 50 volts to a level sufficient to effect migration of the liquid-developed image to the receiving surface during contact of the receiving surface with the image-bearing surface, and contacting together the moist receiving surface and the image-bearing surface, said transfer occurring during contact.

This invention relates to electrography and, more particularly, to the transfer of electrophotographic images and to transfer elements containing these transferred images.

Electrophotographic imaging processes and techniques have been extensively described in both the patent and other literature, for example U.S. Pat. Nos. 2,221,776; 2,277,013; 2,297,691; 2,357,809; 2,551,582; 2,825,814; 2,843,498; 3,060,052; 3,220,324; 3,220,831; 3,220,833 and many others. Generally, these processes having in common the steps of employing a normally insulating photoconductive element which is prepared to respond to imagewise exposure of electromagnetic radiation by forming a latent electrostatic charge image. A variety of subsequent operations, now well known in the art can then be employed to produce a permanent record of the charge image. Often, the charge image is developed and subjected to a transfer process wherein the developed electrophotographic image is transferred to a more permanent receiving surface, that is a receiver, to produce a permanent record of the image.

In developing the latent electrostatic charge image prior to transfer to a receiving surface on which a more permanent record of the developed image is to be produced, the prior art has generally utilized one of two types of development processes. In both types of development processes the latent electrostatic charge image is rendered visible by treatment with a medium comprising electrostatically responsive particles which can be in various forms such as small particles of pigment or in the form of small particles comprising a colorant in a resinous binder. In one development process dry toners are applied to a latent electrostatic image. In a second type of development process, liquid development of the latent electrostatic image is used. In liquid development developing particles are carried to the image-bearing surface in an electrically insulating liquid carrier. Methods of development of this type are widely known and have been described in the patent literature, for example, U.S. Pat. 2,907,674 and Australian Pat. 212,315.

As might be expected, depending upon whether development has been accomplished by use of a dry toner or whether liquid development has been utilized, the art has generally recognized different types of transfer processes for transferring these different types of developed images to a receiving surface. For example, water-moistened, gelatin-coated paper has been used as a receiving surface to effect an adhesive transfer of an image developed by a dry toner. Here the moist gel receiving surface is pressed onto the dry powder image to pick up the toner. This is reportedly useful in producing continuous-tone dry transfer prints although it may suffer from leaving a high proportion of untransferred toner in the areas that were of high density. In this type of transfer using a dry toner and gelatin-coated paper as the receiving surface, resolutions on the order of about 50 to about 100 lines per mm. may be obtained.

On the other hand, a problem associated with the transfer of liquid-developed electrophotographic images has been the problem of selecting a proper receiving surface. In liquid development the liquid carriers for the toner particles are generally highly electrically-insulating hydrophobic liquids and therefore moist receiving surfaces such as those utilized in adhesive transfer of dry toner powder images has been regarded as unacceptable. This is because upon moistening a swellable, polymeric receiving surface, e.g. gelatin, with water, one obtains an electrically conducting, hydrophilic receiving surface.

Accordingly, one faces the problem of attempting to transfer a wet liquid-developed electrophotographic image (which is hydrophobic by virtue of the carrier liquid) to an electrically conducting hydrophilic receiving surface, e.g. a water-moistened gelatin receiving surface.

It is, therefore, an object of the present invention to transfer a wet liquid-developed electrophotographic image to an electrically conducting moist, swellable polymeric receiving surface, e.g. moist gelatin.

It is a further object of our invention to transfer a wet liquid-developed electrophotographic image to processed gelatin-silver image-bearing films.

It is a further object of our invention to transfer high resolution microimages to a swellable polymeric receiving surface coated on an electrically insulating support.

A further object of the invention is to provide a novel transfer element featuring a smudge-resistant transferred image of a liquid-developed electrophotographic image.

Another object of the invention is to provide a transfer element which comprises a transferred image of a liquid-developed electrophotographic image wherein the receiving surface of said transfer element is a processed photographic image-bearing element.

Another object of the invention is to provide an information add-on system whereby sequential images may be transferred to a receiving surface in the space normally provided for a single image, thereby permitting correction, or addition of further information to the original information carried on the receiving surface.

Still another object of the invention is to provide a transfer element wherein a gelatin-silver image-bearing motion picture film is used as the receiving surface and the transferred image provides a sound track for the motion picture film.

These and other objects and advantages of the invention will be apparent from the following description:

In the present invention it has been discovered that effective transfer of a liquid-developed electrostatic charge image from a wet, hydrophobic image bearing surface of a charge-image-bearing member to a hydrophilic, swellable receiving surface carried on an electrically insulating support can be accomplished by moistening the receiving surface prior to image transfer and electrically

assisting the transfer. In accordance with this invention, an electrostatic charge pattern or image is produced on an image-bearing member by any of the suitable techniques known in the art of electrography. One particularly useful means of producing such charge patterns is by electrophotographic techniques. Electrophotography involves the use of a sensitive element typically comprising a conducting support having coated thereon a layer of a photoconductive composition.

As suggested hereinabove, it is quite unexpected to find that a hydrophobic, liquid-developed electrophotographic image wet with a liquid developer carrier can be transferred to a moistened, hydrophilic, swellable receiving surface. The incompatibility between the liquid-developed electrophotographic image wet with hydrophobic developer carrier and the moistened hydrophilic receiving surface would not be expected to permit a useful transfer of the electrophotographic image. Accordingly, it was quite surprising to find that when the moistened receiving surface is given an electrical assist, one can overcome the hydrophobic-hydrophilic incompatibility barrier and promote electrophoretic migration of the hydrophobic, charged toner particles associated with the liquid-developed electrophotographic image into a swollen, moist receiving surface, thereby providing an effective image transfer.

In another aspect of the present invention there is provided a receiving element bearing a transferred image of a liquid-developed electrographic image, said element comprising an electrically insulating support, a hydrophilic swellable receiving surface bearing the transferred electrographic image, the transferred image on the polymeric receiving surface being smudge-resistant and integral with said surface. Receiving elements according to the present invention provide excellent transfer prints and transparencies, especially when compared to the transferred images of normal liquid-developed transfer prints and transparencies which are easily smudged. In fact, since the transferred image on the receiving surface of the receiving element of the present invention appears to be integral with the surface, it is very similar to processed photographic gelatin-silver image-bearing prints wherein the silver image is integral with the gelatin. Accordingly, the abrasion resistance of the transferred images of the receiving elements of the present invention approaches that attained in processed photographic gelatin-silver image systems.

Another advantage of the invention is the extremely high resolution capabilities which the transfer process and receiving elements of the invention provide. That is, it has been found that these elements have approximately the same resolution in the transferred image as the original liquid-developed electrophotographic image on the photoconductor. Moreover, there is little or no degradation of the transferred image due to the transfer process. Accordingly, the receiving elements of the present invention provide excellent microimage information storage members.

According to a preferred embodiment of the present invention the receiving surface comprises gelatin. Gelatin is a relatively inexpensive material; moreover, the technology of gelatin is already well established in the photographic industry and therefore its properties and characteristics are well known. In addition to gelatin, materials useful in the preparation of the transfer receiving surface utilized in the present invention comprise other hydrophilic, swellable polymeric materials. These materials are further characterized in that they are usually considered to be electrically insulating materials when dry. Preferably, the materials also are capable of adhering to the electrically insulating support on which they are carried although intermediate sub-coatings may be utilized to adhere the receiving surface to the support if necessary. When moistened with a water-containing liquid or an alcohol-containing liquid, coating of these poly-

meric materials provide moist receiving surfaces exhibiting a substantial gain in electrical conductivity by virtue of the moistening liquid. Also, when moist, these polymeric materials exhibit at least some degree of swelling. As noted above, a preferred hydrophilic swellable, polymeric material is gelatin. However, a variety of other polymeric materials may also be usefully employed. Such materials would include, for example, both naturally-occurring substances such as proteins, for example, gelatin derivatives, cellulose derivatives, polysaccharides such as dextran, gum arabic and the like; and synthetic polymeric substances such as water soluble polyvinyl compounds like poly(vinyl alcohol), poly(vinyl pyrrolidone), acrylamide polymers and the like.

Moistening the hydrophilic, swellable receiving surface according to the process of the present invention may be carried out by a variety of techniques. For example the receiving surface may be soaked with the moistening liquid, sprayed with the liquid, etc. The moistening liquid itself comprises a liquid composition in which the swellable receiving surface is soluble and which provides a substantial increase in the electrical conductivity of the receiving surface which, when dry, is normally an electrically-insulating material. Water-containing compositions and certain highly polar alcohol-containing compositions comprise preferred moistening liquids useful in the present invention. Examples of various useful polar alcohols include the lower alkyl alcohols having 1 to about 5 carbon atoms in the alkyl chain. Especially useful moistening liquids are aqueous ammoniacal liquid compositions. It will be apparent that the amount of moistening liquid utilized will depend in large part on the particular type of receiving surface. Upon determining the particular composition of a given receiving surface, the amount of moistening liquid useful to substantially increase the conductivity can be readily ascertained by those of ordinary skill in the art. According to a preferred embodiment of the present invention, after contacting the swellable polymeric receiving surface with an amount of liquid effective to substantially increase the conductivity of the receiving surface, any excess liquid may be removed, for example, by squeezing the polymeric receiving surface. Generally, the resultant surface resistivity of useful moistened receiving surfaces according to the present invention is less than about 10^8 ohms per square. For example, typical moistened gelatin receiving materials have a surface resistivity on the order of about 10^2 ohms/sq.

The term "surface resistivity" conventionally refers to measurement of electrical leakage across an insulating surface. In the present specification, however, the term is used with reference to resistance of conducting coatings that apparently behave as conductors transmitting currents through the coating. Resistivity (specific resistance) is the usually accepted measurement for the conductive property of conducting and semiconducting materials. However, in the case of conductive coatings, measurement of the conductive property in terms of surface resistivity provides a value that is useful in practice and involves a direct method of measurement. It should be pointed out that the dimensional units for specific resistance (ohm-cm.) and the unit for surface resistivity (ohms per square) as used herein are not equivalent and the respective measurements should not be confused. For an electrically conducting material whose electrical behavior is ohmic, the calculated resistance per square of a film of such material would be the specific resistance of the material divided by the film thickness, but this calculated resistance for a given material will not always coincide with measured surface resistivity.

As noted, hereinabove, an essential feature of the present invention comprises electrically assisting the transfer of the wet liquid-developed electrographic image to the moistened, receiving surface. The electrical-assist is accomplished by electrically biasing the moist receiving surface with respect to the image-bearing surface of the

liquid-developed electrographic element to a level sufficient to effect migration of the image to the moist receiver during contact of the receiver surface and the image-bearing surface of the electrographic element. This may be accomplished in one embodiment of the present invention by completing an electrical connection between the receiving surface and a potential source so as to change the potential of the moist receiving surface and bias it with respect to the image-bearing surface of the electrographic element. Generally, the potential applied to the receiving surface should be greater than about 50 volts, preferably greater than about 400 volts. In this embodiment of the invention it will be noted that the receiving surface is first moistened and biased as explained immediately hereinabove, before the receiving surface is contacted with the liquid-developed electrographic image.

In another embodiment of the invention, the electrical-assist is provided substantially simultaneously upon contact of the moist receiving surface with the liquid-developed electrographic image. According to this embodiment, the moist receiving surface is biased by electrostatic induction. That is, the liquid-developed image-bearing surface of the image-bearing member may be charged to a positive or negative potential using, for example, a corona charger. Then, while still wet with liquid-developer, the charged electrographic image is gently contacted with a moist receiving surface. As contact is established, the charged image-bearing surface electrostatically induces an opposite charge in the moist receiving surface thereby biasing the receiving surface with respect to the image-bearing surface of the electrographic element and electrically assisting transfer of the electrographic image. In this case, using an induction charge technique, the electrical-assist is provided by the combination of charging the wet liquid-developed electrographic image and inducing an opposite charge in the moist receiving surface as this surface is contacted by the liquid-developed electrostatic image. According to this embodiment of the invention a variety of means may be utilized to charge the liquid-developed electrographic image. Corona charging, as noted above, has been found to give excellent results. In this embodiment, it has generally been found desirable to charge the wet liquid-developed electrographic image to a voltage greater than about 50 volts, voltage in the range of 400-700 being especially useful.

Basically, the actual level of bias required to electrically assist transfer of the liquid-developed image from the surface of the electrographic element to the moist receiver should be sufficient to overcome the attractive force existing between the liquid-developed image and the surface of the electrographic elements and the forces contributing to the hydrophobic-hydrophilic incompatibility existing between the wet-hydrophobic liquid developed image on the electrographic element and the moist hydrophilic surface of the receiving sheet. Of course, therefore, the actual bias level required will vary depending upon the particular liquid developer used, the particular photoconductive composition used, the degree of hydrophilicity and hydrophobicity exhibited, respectively, by the moist receiving surface and moist photoconductive element, and the like.

As noted above, the transfer process of the present invention is especially adapted for transfer of liquid-developed electrographic images, for example, liquid-developed xerographic images. Liquid developers may generally be characterized as a mixture of developing particles, i.e. toner particles, in an electrically-insulating hydrophobic liquid carrier. This developer can be flowed over a surface bearing an electrostatic image, or the image-bearing surface can be immersed in a tray of liquid developer. It can also be sprayed or rolled on to the surface. When appropriate developer or toner particles are dispersed in a properly selected liquid carrier, they acquire an electrophoretic charge of appropriate polarity.

Deposition of the developer particles on the charge image is an example of the phenomenon known as electrophoresis or cataphoresis. Greater detail concerning examples of various types of liquid developers may be obtained by reference to the following publications hereby incorporated into the present specification by reference thereto: Straughan, U.S. Pat. 2,899,335, issued Aug. 11, 1959; K. A. Metcalfe in a paper entitled "Liquid Developers for Xerography" published in the Journal of Scientific Instruments, February 1955, vol. 32; Metcalfe et al., U.S. Pat. 2,907,674 issued Oct. 6, 1959; Greig, U.S. Pat. 3,053,688 issued Sept. 11, 1962; Metcalfe et al., U.S. Pat. 3,058,914 issued Oct. 16, 1962; Greig, U.S. Pat. 3,076,722 issued Feb. 5, 1963; and York, U.S. Pat. 3,135,695 issued June 2, 1964. In general, as will be apparent from a study of the above-identified publications, liquid developers suitable for use in the present invention comprise a hydrophobic electrically insulating liquid carrier and developing particles admixed therein. Generally, the liquid carrier has a low dielectric constant less than about 3.0, a resistivity greater than about 10^{10} ohm-cm., and comprises a hydrocarbon or mixture of different hydrocarbons. These liquids and liquid mixtures may be exemplified by materials such as benzene, toluene, turpentine, carbon tetrachloride, mixed halide hydrocarbons, cyclopentane, cyclohexane, petroleum distillates, mixtures thereof, etc. In addition to these hydrocarbon liquid carriers, certain other liquid carriers such as dimethyl polysiloxane may be used. See U.S. Pat. 3,053,688 concerning the use of dimethyl polysiloxane.

The developer particles admixed in a liquid carrier are finely-divided particles capable of carrying an electrostatic charge. Various types of such materials for use in liquid developers are well-known in the art. For specific details concerning the use of some of these materials reference may be had to the literature noted hereinabove. These developing particles, or toners as they are called, contain pigment or dye which may be prepared from numerous diverse organic and inorganic materials including talcum powder, aluminum bronze, carbon dust, gum copal, gum sandarac, carbonyl iron and iron oxides, especially magnetic iron particles, etc. For optimum efficiency, it is desirable to employ a pigment in which a preponderance of the particles acquire a charge of one sign, either positive or negative. Presented herein accordingly are a number of pigments which have a negative particle charge in a liquid carrier and a number of pigments which acquire a positive particle charge in liquid carrier. Several of these pigments of each type are given in the table below. The carrier for determining the charge was cyclohexane.

TABLE I

Pigment	Manufacturer
Negative Particle Pigments	
Carbon Black G.....	Fisher Scientific Co.
Pyramide cerise toner RA 520.....	Factor, Max & Co.
Fast mono green toner G-FG 430.....	General Dyestuff Co.
Pigment yellow LX CyB-340.....	Factor, Max & Co.
Solfast green 63100.....	Sherwin-Williams Co.
Positive Particle Pigments	
Aluminum powder (flake).....	
Antimony sulfide.....	
Cupric sulfide.....	
Carbonyl iron.....	General Aniline and Film Corp.
Lamp black, Germantown.....	Columbian Carbon Co.
Mapico black.....	Do.
Nigrosine S.S.B. No. 5.....	General Aniline and Film Corp.
Grassol black.....	Geigy Co., Inc.
Monastral fast blue B.....	E.I. du Pont de Nemours and Co.
Dresden blue 81451.....	Imperial Paper and Color Corp.
Pyramid germanium toner RA 500.....	Factor, Max & Co.
Selkirk red X-2028.....	Imperial Paper and Color Corp.
Winthrop red X-1666.....	Do.
Britone red MCP974.....	Sherwin-Williams Co.
Britone red MCP1290.....	Do.
Duratint green 48-238.....	Factor, Max & Co.
C.P. light yellow X-1799.....	Imperial Paper and Color Corp.
W81 benzidine yellow anilide.....	Sherwin-Williams Co.

The particle size of the toner particles should generally be in the range of from about 0.1 to about 20.0 microns. Generally, with a smaller particle size toner, one obtains better resolution in the resultant prints. Thus, for example, where continuous tone copy is to be developed using liquid developers, it is desirable to use fairly small particle sizes on the order of about 1 micron or less to obtain optimum resolution. The toner particles are generally admixed with the carrier liquid by some type of milling or combined mixing and milling operation. Other additives may also be included in the developer, e.g. stabilizers, binders, driers, etc. Ordinarily, the final developer composition contains from about 0.01 to about 10 percent by weight toner and from about 90 to about 99 percent by weight carrier liquid.

As noted hereinabove, the particular method of applying the liquid developer to the image to be developed is not critical to the present invention and may be accomplished by any of several conventional methods, for example, by immersing the image-bearing surface in a tray of liquid developer or by passing the image-bearing surface between conducting rollers or relatively conducting rollers which are thoroughly wetted with the developer. One essential feature of the present invention, however, is that the image-bearing surface remains wet with developer during the transfer operation, i.e. the liquid-developed electrophotographic image-bearing surface must be wet with developer at the time of contact with the moistened receiving surface. Otherwise, if the liquid carrier has substantially evaporated, the now dry toner particles are left adhered to the electrophotographic image and electrophoretic migration of the toner particles from the image-bearing surface to the receiving surface becomes much more difficult. Of course, this feature of the invention also provides a significant advantage because the invention is not restricted to fast drying liquid developers or to the use of developers having additives promoting fast-drying time.

A wide variety of electrically insulating supports are useful for carrying the swellable polymeric receiving surface. Suitable supports would include such materials as wood, glass, paper including coated paper such as polyethylene coated paper; polymeric materials such as polyolefins, for example, polyethylene, polypropylene, etc.; polyesters such as poly(ethylene terephthalate) etc.; and other suitable support materials. A particularly useful support material is manufactured under the name of Estar and is a poly(ethylene terephthalate) having an inherent viscosity (η) of about 0.6. Of course, in a preferred embodiment of the invention wherein the receiving surface comprises a silver image-bearing gelatin surface, for example, motion picture film, the support is a material suitable as a film support.

The hydrophilic material comprising the receiving surface may be applied to the support in a variety of ways. Suitable coating means would include dip coating, spray coating, extrusion hopper coating, applications on a continuous coating machine; etc. Coating coverages of the swellable polymeric receiving surface can vary widely depending upon the material used and the results desired. Useful results are obtained with coverages of from about 10 to about 1000 milligrams per square foot.

The electrophotographic elements used in the present invention for production of the original liquid-developed electrophotographic image to be transferred contains a photoconductive layer which can be prepared from a variety of materials. In general, this layer is prepared by dispersing a photoconductor in a resinous binder and coating the resultant dispersion on the conductive layer. Photoconductors suitable for use in the photoconductive layer can include inorganic, organic and organometallic materials. Useful photoconductors would include zinc oxide, titanium dioxide, organic derivatives of Group IVa and Va metals such as those having at least one amino-aryl group attached to the metal atom, aryl amines, poly-

arylalkanes having at least one amino substituent and the like.

The following Table A is a partial listing of U.S. patents disclosing a variety of organic photoconductive compounds and compositions which are useful.

TABLE A

Inventor:	U.S. Pat. No.
Schlesinger -----	3,139,338
Schlesinger -----	3,139,339
Cassiers -----	3,140,946
Davis et al. -----	3,141,770
Ghys -----	3,148,982
Cassiers -----	3,155,503
Schlesinger -----	3,257,202
Sues et al. -----	3,257,203
Sues et al. -----	3,257,204
Fox -----	3,265,496
Kosche -----	3,265,497
Noe et al. -----	3,274,000

The photoconductive layer can be applied by a variety of means such as swirl coating, spray coating, extrusion hopper coating, etc. The amount of photoconductor in the layer can be varied from about 10 to about 60 percent by weight of the total solid.

In addition, if desired, a barrier layer can be interposed between the conductive layer and the photoconductive layer. In general, such barrier layers are formed of a resinous material. Particularly useful barrier materials include polycarbonates as disclosed in Gramza and Perry copending U.S. application Ser. No. 12,470 entitled "Electrophotographic Element," filed Feb. 18, 1970, and now Pat. No. 3,554,742. The coating coverages of these barrier layers can be varied from about 0.04 to about 0.50 g./ft.² based on the dry weight of the resin.

The following examples will further illustrate the present invention.

EXAMPLE 1

In this example an adhesive transfer of a liquid-developed electrophotographic image to a moist receiving sheet without an electrical assist is attempted. A 35 mm. strip of organic photoconductor coating containing a Vitel polyester binder; an organic photoconductor of 4,4'-diethylamino-2,2'-dimethyltriphenylmethane; and a sensitizing amount of a pyrylium salt sensitizer, namely the tetrafluoroborate salt of 4,6-bis (p-methoxyphenyl)-2,2-pentylloxystyrylpyrylium, is negatively charged, contact exposed to a silver positive transparency of a variable density sound track, and liquid-developed with an Isopar G (an isoparaffinic hydrocarbon liquid having a boiling point in the range of 145° C. to 185° C. made by the Humble Oil and Refining Company) suspension of positively charged toner particles comprising a mixture of linseed oil and as a colorant, Pigment Blue 19, in a binder of modified alkyd resin, the Color Index of these toner particles being 42750.

The resulting sound track electrophotographic image, still wet with liquid developer, is firmly pressed into contact with the gelatin side of a strip of processed motion picture film which has been soaked in water and squeezed just prior to contact. Care is taken to avoid electrical connection of any kind between the moist gelatin receiving sheet of film and the conducting substrate of the photoconductor, thus any image transfer which occurs depends solely on the tacky or adhesive nature of the moist gelatin of the motion picture film.

Separation of the photoconductor motion picture film sandwich indicates that virtually no image transfer of the sound track electrophotographic image to the motion picture film has taken place. It is apparent that the adhesive nature of the moist gelatin is insufficient to overcome the natural hydrophobicity of the petroleum distillate-wet liquid developed xerographic image to produce an adhesive type transfer.

This experiment is repeated several times with different wet liquid developed images with the same result: very poor, if any, transfers occurs even with heavy pressures.

EXAMPLE 2

In this example a positive-positive transfer using an electrical assist according to the present invention is illustrated. Initially, the same procedure is followed as noted in Example 1 hereinabove, except that a transfer bias of -500 volts is applied to the moist, processed motion picture film serving as a moist-gelatin containing receiving sheet. This is accomplished by clamping an electrical contact with -500 volts on one end of the moist gelatin receiving sheet, there being sufficient conductivity in the water-wet gelatin layer of the film to bias the entire strip of moist motion picture film. A return lead is connected to the conducting layer underlying the photoconductor (which carries the liquid-developed electrophotographic image) to complete the circuit.

Surprisingly, this bias-type of electrical assist results in excellent transfer of the liquid-developed sound track image on the photoconductive layer to the water-moist gelatin containing layer of the motion picture film when these two layers are gently contacted together. At contact time, both layers are moist, the photoconductive layer is moist with the liquid developer described in Example 1 hereinabove and the motion picture film is moist with water. The electrical bias assist of the present example destroys the normal oleophobic surface barrier of the gelatin containing motion picture film thereby allowing electrophoretic penetration by the toner particles from the liquid developed xerographic image to the moist gelatin layer. The result is a high quality positive print of the original sound track contained on the hardened-gelatin of the processed film strip.

An unexpected advantage discovered upon drying of the print is that the transferred image of the sound track appears as an integral part of the gelatin surface of the silver image bearing film. Accordingly, the positive print contained on the film strip is more highly smudge or abrasion resistant than is a normal liquid-developed electrophotographic print of the original sound track made directly on the photoconductor surface with the same liquid-developer.

EXAMPLE 3

In this example a sample of organic photoconductor coating described in Example 1 is charged negatively to 600 volts, contact exposed to a positive-appearing variable density sound track and platen processed using the liquid developer described in Example 1 hereinabove. The resulting liquid-developed positive-appearing electrophotographic image is recharged to a +600 volts under a corona charger, and while still wet with liquid developer, is gently rolled into contact with a soft, moist gelatin receiving surface of water-moistened processed silver image bearing motion picture film. Both the receiving surface and the conducting substrate of the photoconductor are grounded.

As a result of the above procedure a high quality positive print of the variable density sound track is produced on the gelatin receiver, i.e., the motion picture film. Prior to this transfer process, the gelatin receiver, i.e., the motion picture film had been cleared and fixed in a sodium thiosulfate solution which did not contain any hardener. In addition, the gelatin receiver had been soaked in water and squeegeed just prior to use in this transfer operation.

EXAMPLE 4

In this example the procedure of Example 3 hereinabove is followed exactly except that the liquid-developer wet photoconductor and the moist gelatin receiving surface are not grounded, but rather remain electrically unconnected during the transfer operation. In this case, it is found that the corona recharging to +600 volts of the liquid-developed positive-appearing image on the photo-

conductor acts to electrostatically induce an opposite negative charge of approximately equal magnitude in the moist gelatin receiver as the gelatin receiver and the photoconductor are contacted together during transfer. Accordingly, in this example, as in Example 3 and in Example 5 (noted below), the electrical assist is a combination of recharging the still wet liquid-developed positive-appearing image on the photoconductor and inducing an opposite charge in the moist gelatin receiver as the photoconductor and receiving surface are contacted together. As a result, there is obtained a high quality positive print of the original sound track on the gelatin containing, motion picture film strip which is used as a receiving surface.

EXAMPLE 5

In this example the transfer process of the present invention is used to obtain a negative print of a negative-appearing original micro image containing a continuous tone step wedge. In this example an organic photoconductor coating identical to that utilized in Example 1 hereinabove is charged negatively to 600 volts and exposed to a negative-appearing micro image containing a continuous-tone step wedge. The photoconductor coating has been platen-processed using the liquid developer noted in Example 1 hereinabove. After development, the still-wet negative dupe on the photoconductor is recharged to approximately +600 volts with a corona charger. A receiving surface which comprises a previously processed 35 mm. motion picture strip is moistened with water and squeegeed to remove excess water. The still-wet negative dupe on the photoconductor and the moist receiving surface are grounded and then the photoconductor and the receiving surface are gently rolled into contact with each other and transfer is accomplished. The resulting transfer image on the moist gelatin receiving surface is a high quality, high resolution, continuous-tone duplicate of the negative-appearing micro image original.

EXAMPLE 6

In this example a resolution check is made to demonstrate the high resolution capabilities of the transfer process of the present invention. In this example an organic photoconductive coating, as described in Example 1 hereinabove, is charged negatively and exposed to a positive-appearing resolution chart, platen-processed with the liquid developer composition described in Example 1 hereinabove, and then while still wet, the positive dupe of the chart contained on the exposed photoconductor coating is recharged to approximately +600 volts. The still-wet positive dupe of the chart on the photoconductive surface is then transferred as described in Example 4 hereinabove to a moist gelatin receiving surface identical to that utilized in Example 4 above. After transfer, resolution of the transfer print on the gelatin receiving surface is measured and found to be 224 lines per millimeter.

EXAMPLE 7

In this example the transfer process of the present invention is utilized in conjunction with a negative-positive reversal. In this example an organic photoconductive coating as described in Example 1 hereinabove, is charged positively to 600 volts and exposed to a negative-appearing micro image having a continuous-tone wedge. The electrostatic charge pattern obtained on the exposed photoconductive coating is reversal developed in the processing platen by applying a +600 volt bias on the facing electrode forcing the positively charged liquid developer described in Example 1 above into the discharged areas of the exposed photoconductive coating in such a manner to afford a toner reversal. At this point a moist gelatin receiving surface is prepared by clearing and fixing in standard Kodak F-5 fixer a motion picture film. This provides a hardened gelatin receiving surface. This hardened, processed gelatin receiving surface is then presoaked in water and squeegeed to remove excess water.

At this point the receiving surface and the liquid developed electrophotographic image are grounded and transfer is then accomplished by gently rolling together the moist gelatin receiving surface and the reversal developed photoconductive coating still wet with liquid developer. In this case transfer is accomplished by an electrical assist utilizing electrostatic induction. That is, the positive charge on the photoconductive layer induces a negative charge on the receiving surface which acts to break the oleophobic-barrier presented by the moist gelatin receiving surface and allows the positively charged toner particles of the liquid developer to migrate to the receiving surface. In this case, the electrical assist comprises the combination of repelling positive charge on the photoconductive layer and the induced negative charge in the gelatin receiver. As a result a high quality, high resolution, continuous-tone positive of the negative-appearing original microimage is obtained on the moist motion picture film serving as a receiving surface.

This same procedure is repeated to obtain a resolution check. It is found that the resulting transfer image exhibits a high resolution of 200 lines per millimeter.

EXAMPLE 8

In this example the add-on capability of the transfer process of the present invention is demonstrated. In this example, a positive-appearing microimage on a moist gelatin receiving surface is obtained using a procedure and materials identical to that described in Example 6 hereinabove. After drying and storing the positive-appearing microimage of the negative-appearing microimage original for a period of 48 hours, the motion-picture film strip containing the positive-appearing microimage print is res soaked in water and squeezed to remove excess water. At this point the procedure of Example 6 is repeated and a second positive image of the negative-appearing microimage original is obtained in an adjacent clear area of the motion picture film. This clearly demonstrates the add-on capability of a transfer process of the present invention.

EXAMPLE 9

This example again demonstrates the add-on capability of a transfer system of the present invention. As in Example 7 hereinabove two positive-appearing images of a negative-appearing original are transferred to a single moist receiving surface. In this case the two images are laid down at right angles to each other sequentially and superposed in such manner that the toned areas of the images on the moist motion picture film receiving surface overlap in some areas to double the density. Upon examination of the receiving surface there is no evidence of interimage effects in the superposed areas. Both transfer images are equally sharp. In addition, this example clearly demonstrates the capability of the present transfer system for three-color subtractive photography. All that is needed are three liquid developers having toner particles therein with the requisite colors and with transfer and charge characteristics identical or closely similar to that of the toner particles described in Example 1 hereinabove.

Although the above examples utilize processed gelatin-containing receiving elements, e.g. processed motion picture film, it will be apparent that an unprocessed gelatin-containing or other hydrophilic swellable polymer-containing receiving element may be used. Similarly, although silver halide is present in the gelatin-containing receiving elements used in the above examples, it is not essential to the practice of the present invention. Rather, use of the present invention in conjunction with processed silver halide photographic film is illustrated simply to demonstrate a preferred embodiment of the invention.

In addition, it will be apparent that, if desired, various addenda, e.g. soluble salts, may be added to the water and alcohol containing liquids applied to the surface of the receiving elements used in the present invention. Such

addenda may be useful to increase the electrical conductivity of these liquids, or to mordant the transferred image.

The invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the scope and spirit of the invention.

We claim:

1. A method of transferring a liquid-developed electrostatic charge image from a wet, hydrophobic image-bearing surface of a charge-image-bearing member to a hydrophilic, swellable receiving surface carried on an electrically insulating support which comprises moistening the receiving surface prior to transfer with a hydrophilic liquid of water-containing compositions or alcohol-containing compositions, in an amount effective to increase the electrical conductivity of said receiving surface to a value less than about 10^6 ohm/sq., electrically biasing the moist receiving surface utilizing an applied potential greater than about 50 volts to a level sufficient to effect migration of the liquid-developed image to the receiving surface during contact of the receiving surface with the image-bearing surface, and contacting together the moist receiving surface and the image-bearing surface, said transfer occurring during contact.

2. The method according to claim 1 wherein said charge-image-bearing member is a photoconductor-containing element and wherein said hydrophilic swellable receiving surface comprises a polymeric material.

3. A method of transferring a liquid-developed electrostatic charge image from a wet, hydrophobic image-bearing surface of a charge-image-bearing member to a hydrophilic, swellable receiving surface carried on an electrically insulating support which comprises moistening the receiving surface prior to transfer with a hydrophilic liquid of water-containing compositions or alcohol-containing compositions, in an amount effective to increase the electrical conductivity of said receiving surface to a value less than about 10^6 ohms/sq., and substantially simultaneously (a) electrically biasing the moist receiving surface utilizing an applied potential greater than about 50 volts and (b) contacting together the moist receiving surface and the image-bearing surface, said moist receiving surface electrically biased by charging the wet, hydrophobic image-bearing surface and electrostatically inducing an opposite charge on the moist receiving surface as it is contacted with the charged wet image-bearing surface, said moist receiving surface biased to a level sufficient to effect migration of the liquid-developed image to the receiving surface during contact of the receiving surface with the image-bearing surface.

4. The method according to claim 3 wherein the wet image-bearing surface is charged to a voltage within the range of from about 400 to about 700 volts.

5. The method of claim 3 wherein said receiving surface is a processed silver halide photographic film element.

6. The method of claim 3 wherein said receiving surface comprises a processed silver halide-gelatin motion picture film and wherein said transferred image provides a sound track for the film.

7. The method of claim 3 wherein said receiving surface is suitable for use as a microimage information storage member in an information storage system, said storage member capable of receiving additional transferred liquid-developed electrographic images in areas of the receiving surface already bearing at least one transferred image.

8. A method of transferring a liquid-developed electrostatic charge image from a wet, hydrophobic image-bearing surface of a charge-image-bearing member to a gelatin receiving surface carried on an electrically insulating support which comprises moistening the receiving surface prior to transfer with a hydrophilic liquid of water-containing compositions or alcohol-containing compositions,

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in an amount effective to increase the electrical conductivity of said receiving surface to a value less than about 10^6 ohms/sq., electrically biasing the moist receiving surface utilizing an applied potential greater than about 50 volts to a level sufficient to effect migration of the liquid-developed image to the receiving surface during contact of the receiving surface with the image-bearing surface, and contacting together the moist receiving surface and the image-bearing surface, said transfer occurring during contact.

9. The method according to claim 8 wherein said charge-image-bearing member is a photoconductor-containing element.

10. A method of transferring a liquid-developed electrostatic charge image from a wet, hydrophobic image-bearing surface of a charge-image-bearing member to a hydrophilic, swellable receiving surface carried on an electrically insulating support which comprises moistening the receiving surface prior to transfer with a hydrophilic liquid of water-containing compositions or alcohol-containing compositions, in an amount effective to increase the electrical conductivity of said receiving surface to a value less than about 10^6 ohms/sq., electrically biasing the moist receiving surface by electrically connecting the moist receiving surface to a potential source greater than about 50 volts, said receiving surface biased to a level sufficient to effect migration of the liquid developed image to the receiving surface during contact of the receiving surface with the image-bearing surface, and contacting together the moist receiving surface and the image-bearing surface, said transfer occurring during contact.

11. The method of claim 10 wherein said receiving surface is suitable for use as a microimage information storage member in an information storage system.

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12. The method of claim 10 wherein said receiving surface is a processed silver halide photographic film element.

13. The method of claim 10 wherein said receiving surface comprises a processed silver halide gelatin motion picture film and wherein said transferred image provides a sound track for the film.

14. The method according to claim 10 wherein said receiving surface is electrically biased utilizing an applied potential greater than about 400 volts.

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